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REDISCOVERING THE OLD TREASURES OF CARTOGRAPHY — WHAT AN ALMOST 500-YEAR-OLD MAP CAN TELL TO A GEOSCIENTIST

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Tabula Hungariae (1528), created by Lazarus (Secretarius), is an almost 500 year-old map depicting the whole Pannonian Basin. It has been used for several geographic and regional science studies because of its highly valued information context. From geoscientific point of view this information can also be evaluated. In this contribution an attempt is made to analyse in some extent the paleo-hydrogeography presented in the map, reconsidering the approach of previous authors, assuming that the mapmaker did not make large, intolerable errors and the known problems of the cartographic implementation are rather exceptional.

According to the map the major lakes had larger extents in the 16th century than today, even a large lake (Lake Becskerek) ceased to exist. Concerning the fluvial pattern, a detailed analysis is possible for the Danube. Important changes can be implied at the Danube Bend, and there was a stronger tendency of island formation (i.e., tendency towards braided style) downstream from the present day Budapest. In most of the cases the assumption of the depicted islands is feasible. The existence of a few paleo-islands not present today can be validated by historical sources as well. Furthermore, the river Sárvíz, today a less important watercourse, might have had more importance in the transport at that time, probably due to its larger water discharge.

Summarizing the observations it seems that these are indications of larger discharge values and/or a wetter climate in the Central Pannonian Basin in the 16th century.

Keywords: Danube; environmental change; historical maps; palaeohydrography; Pannonian Basin; river avulsion

Introduction

The onset of the digital era has changed the value of the cartographic heritage at least in two senses: a) the old maps in their digitized forms are easy to redistribute and since there is practically no copyright problem with them, they may appear in electronic databases and even in the internet (e.g., Guszlev 2003), b) if the cartographic base is known or can be reconstructed, they can be integrated into geographic information systems (GIS; e.g., Timár 2004, Timár et al. 2006a, Biszak et al. 2007, Timár and Molnár 2008).

Owing to this development more and more researchers recognize the value of such maps, since sometimes implicit information is also contained in them. The mapmaker could draw something evident on the map that today is by far not so obvious because the landscape has dramatically changed since then. To recognize such hidden information in the archive maps the researchers need to develop a certain routine, they have to be open-minded and they also need some luck.

With the increasingly widespread use of such historical maps, more and more information can be gathered concerning the environmental reconstructions. Of course, most of the archive maps cannot provide spatial accuracy that would be needed, but they still represent a fair trade-off between the accuracy and the wanted historical information.

In geoscience 500 years in really a short moment, however, if one has a map that show environmental information of the situation a half thousand years ago (in other words, 0.5 ka or 0.0005 Ma) it is valuable, since the changes can turn to be considerable. 500 years is the time range that a geoscientist may find interesting.

For the Pannonian Basin there is an almost 500-year-old map, the *Tabula Hungariae* (1528) compiled by Lazarus (Secretarius) and published by Tanstetter in Ingolstadt (Germany). This map is a real milestone in the cartography: this masterpiece has been declared an "item of documentary heritage of exceptional value" by the UNESCO including it in the Memory of the World Register (UNESCO 2007). Beside of its technological novelty and aesthetic beauty, this map provides invaluable data for environmental historical analysis. This contribution is an attempt to summarize some geoscientific implications that this map allows and relate them to considerations of previous authors.

Lazarus and his map

The 16th century has seen a major change in dominance pattern of Eastern Europe. The unified Hungarian forces were defeated by the emerging Turkish Empire in the battle of Mohács in 1526. From military point of view the necessity was imminent to compile all available strategic spatial information into a map. *Tabula Hungariae* (Lazarus 1528) at the time of the compilation (Fig. 1), just two years after the aforementioned battle (also pictured in the map) fulfilled this task. Among others the information on the yet uncontrolled watercourses was extremely substantial, because they served as routes for supply and reinforcements, as well as obstacles to cross for the armed forces in deployment. Their accurate mapping became an important issue at that time.

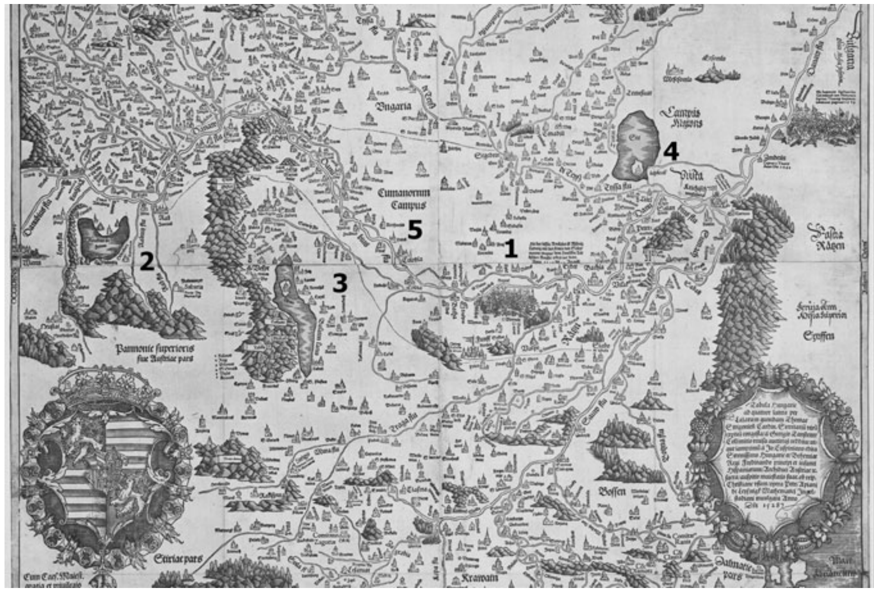

Fig. 1. A part of *Tabula Hungariae* (Lazarus 1528) representing the Central Pannonian Basin. The battle of Mohács in 1526 is also depicted (1). Important areas considered in the paper: 2 – Lake Neusiedl, 3 – Lake Balaton, 4 – Lake Becskerek (see also in Fig. 2), 5 – central Danube Valley (see also in Fig. 6)

Lazarus (Secretarius) served as a secretary at the episcopal center of Esztergom (Strigonium) at the time of archbishop Thomas Bakócz (1442–1521). He compiled his map from various sources; probably certain parts were mapped or revised by himself. This map is the first presenting a whole country in continental Europe, and using special printing technology (Plihál 1990, 2003, Török 1996, 2003). From geoscientific point of view it is also important, since it covers practically the whole Pannonian Basin, although the mapping accuracy and the cartographic details vary somewhat within the map.

The map could not have been drawn according to modern cartographic principles applied today, however, the approach of the compiler was consistent enough to provide a good overview and even some detailed information can be derived from its data content (Cholnoky 1943, Irmédi-Molnár 1964, Hrenkó 1974, Érdi-Krausz 1982, Bede 1987, Lotz 1988).

Theoretical considerations

The map was already analysed cartometrically earlier (e.g., Stegena 1976, 1982), and in a few previous studies georeferencing attempts have also been carried out. The approximate rectification in recent coordinate systems (Molnár et al. 2008) paved the way to use it in quantitative studies (Székely et al. 2007). Recently it has been shown (Timár et al. 2008b), that the previously assumed Ptolemian projection may be used to rectify *Tabula Hungariae* with surprisingly good accuracy.

Since we are interested in the geoscientific content of the map in the light of environment change, its georeference should be reconstructed as far as it is possible. Molnár et al. (2008) found that applying a quadratic fit provides a generally acceptable error level.

Despite the criticism of some previous authors pointing out the errors in the map, several studies (e.g., Székely et al. 2006) demonstrate that the drainage is extremely well mapped in *Tabula Hungariae*. If we believe that the hydrography is correct at the contemporaneous level of knowledge, with a certain accuracy we can extract valuable information that otherwise would not be available for that period of time. The only problem is the verification of these almost 500-year-old pieces of information.

What we can do is to analyse the differences between the features drawn in the map and the actual hydrographical situation. These differences (at least the most obvious ones) were mostly considered as inconsistencies or even errors by some previous authors. In the present contribution, however, the approach is that Lazarus was basically right, he and his co-workers carried out an accurate mapping. So the differences can be regarded as a sort of indications of environmental change. Although there might be places or regions where this approach is false, some examples will be considered here to demonstrate the usefulness of this assumption.

The extent of the major Pannonian steppe lakes in Lazarus' map

In the Pannonian Basin, especially in its low relief alluvial plains like the Great Hungarian Plain (GHP) and the Little Hungarian Plain (LHP), the recent drainage pattern can be categorized into three basic groups: some (typically hilly) regions show classic dendritic drainage; in other regions a meandering/braided river systems can be found according to the actual discharge and sediment load conditions (see e.g., Timár 2003); and some areas are characterized by extremely low drainage density combined with smaller or larger lakes.

In the alluvial parts of the Pannonian Basin (especially in the GHP) where river meandering takes place, oxbow lakes are very typical and numerous, but they are limited in size. The larger lakes are shallow or very shallow steppe lakes having a considerable extent. Less frequently smaller, temporary or perennial, extremely shallow playa lakes also occur.

In the case of the steppe lakes, despite their shallow hosting depression, the extent of the lake may reach several tens of kilometers (e.g., Lake Balaton, Lake Neusiedl/Fertő-tó; Fig. 1). Obviously the lake level fluctuations may have a considerable effect on the actual extent of the lakes. That is the reason why historical maps might provide geoscientific information: with the assumption of accurate cartographic surveying work the actual extent of the water body may allow implications on the contemporaneous lake level.

Fig. 2. The "Lake Becskerek" in Lazarus' map. Note the inlet of river Temes and the two outlets

a) Lake Becskerek

The most striking difference is the extent (or even the existence) of major lakes. Beside of the aforementioned two lakes (Lake Balaton, the largest and Lake Neusiedl, the second largest in Central Europe) there is a major lake around the city of Beczkerek (in modern Hungarian: Becskerek, today Zrenjanin, in Serbia) where there is no such a lake today at all (Fig. 1). As it was recently pointed out (Timár et al. 2008a), the unfortunate 2005 flood event in the Banat region filled an area with similar extent reconstructing the lake temporarily. The appearance and the comparably large size of the ephemeral or temporary "Lake Becskerek" (Timár et al. 2008a; Fig. 2) demonstrates the importance and usefulness of the application of historical maps in palaeohydrography. Since there is no difference in the drawing style of the three aforementioned lakes, and the city of Becskerek seems to be fortified by the surrounding lake, as speculative working hypothesis (partly extending the interpretation of Timár et al. 2008a), it is possible to postulate that Lake Becskerek was a regular perennial steppe lake, probably shallow at places. Even if this assumption holds, Lake Becskerek, unlike its modern counterpart, the Lake Neusiedl, had to have multiple inlets and one or more outlets. (It is to be noted, that the 16th century Lake Neusiedl having larger L-shape extent, most probably also had an outlet towards E, see below.)

b) Lake Balaton

The outline of the Lake Balaton has also a different extent and shape in the Lazarus' map than today: beside of the differences in the shape, Tihany peninsula, a remnant of a volcanic edifice, is situated almost in the middle of the Lake Balaton. Today, a flat isthmus joins the degraded volcanic edifice to the Balaton Upland forming the peninsula character, while in Lazarus' map it is unquestionably an island. If we assume this situation at that time to be real, it would mean a higher water level of the lake. Some previous authors (most prominently Bendefy 1968) considered it as a fact, but attributed this situation to artificial control of the water level for defense purposes. Nevertheless, this interpretation is debated in the Hungarian literature. Virág (1998) provided a good overview on this debate; he himself concluded that Lazarus was wrong. The counterarguments typically deal with the present day elevation of the isthmus that would involve a much larger inundation in the south, but even the workers who deny the island state of Tihany in the late 15th century, assume somewhat higher water level than today, and an artificial defense channel through the isthmus.

According to our concept followed in this paper, the island state of Tihany should be considered. Beside of the somewhat higher water level we have to reflect on two other factors. There is evidence that the water level variation has been found to be 3–4 feet (ca. 90–120 cm; Zlinszky and Molnár 2009) more than two centuries later. It is possible that even more humid conditions (that most authors found possible in this time) with some decadal/centennial precipitation events would produce such variations in the water level in the time of Lazarus as well.

Furthermore, the authors denying Tihany as an island did not take into account the differential vertical crustal movements that can modify the situation here even in this relatively short period of time. It is known that the Balaton Upland in the north uplifts relative to the southern Somogy area according to repeated precise levelling (Joó 1992). Although the accuracy of this method is not enough to constrain the relative uplift of the two shorelines in the N and in the S with the requested precision, 0.3–0.5 m relative uplift cannot be excluded (Timár et al. 2006b). If we account for the aforementioned effects and take into consideration the digital elevation model of the present topography, the higher water level and the Tihany as an island cannot be excluded. There is historical evidence that at other places the inundation pattern argue for higher contemporaneous water levels (e.g., Csongrádi et al. 2002, 2003 and references therein).

c) Lake Neusiedl (Neusiedlersee/Fertő-tó)

Concerning the water level, the same applies to the counterpart of Lake Balaton more to the NW: the shape of the Lake Neusiedl (Neusiedlersee in German ("Newsidler See"), Fertő-tó in Hungarian ("Fertow")) seems to be different to the present one (Fig. 3 a). Most probably this difference can be accounted for the varying lake level, too. In the last century there is evidence for strong lake level undulations, including the complete drying out in 1870s as well (Draganits et al. 2006). Lazarus' map shows an L-shaped form, that was due to the inundated state of the Hanság/Waasen area (Draganits et al. 2008). Since the lake level dropped relatively considerably, partly due to human influence, the eastern embayment of the lake ceased to exist, so the lake lost its L-shape that was traceable in archive maps for more than four centuries (Draganits et al. 2008). The most important argument that Lazarus map shows the real shape and extent of lake is provided by the previous authors in analyzing later historical maps: at a given water level all the historical settlement of the Seewinkel ('lake corner') become aligned

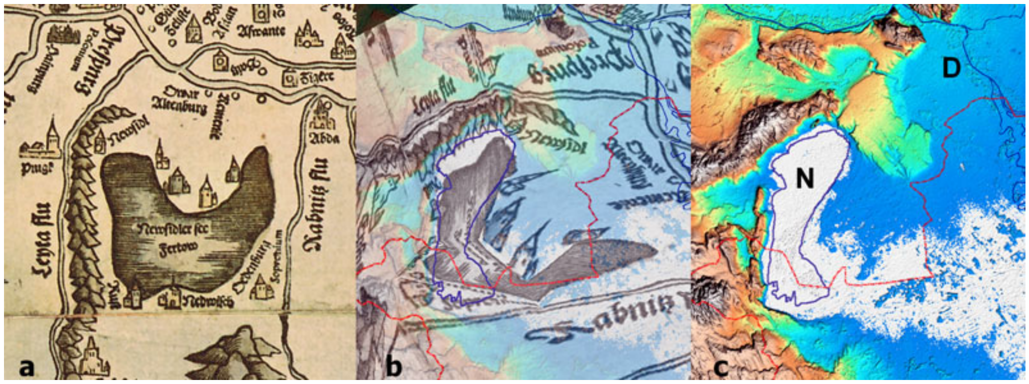

Fig. 3. a) The Lake Neusiedl in original layout of Lazarus' map. Note the four settlements in the Seewinkel ("lake corner") that can be identified as: Podersdorf, Illmitz, Pamhagen and Andau (left to right). Today Andau is not on the shore. The other settlement around the lake: Neusiedl am See ("Newsidl"), Rust, Mörbisch ("Nedwisch"), Sopron ("Oedenburg" or "Sopronicum"). Leyta flu: River Leitha. b) The rectified version using the aforementioned points. The red dot-dashed line (also in (c)) represents the present-day border of Austria and Hungary. c) A shaded relief map of the area based on the SRTM digital terrain model (e.g. Farr et al. 2007) left white below 115 m a.s.l., also visible in the background for comparison in (b); N: Neusiedlersee; D: Danube

on the modified shoreline. The name of the area (lake corner) also indicates that there should be a 'corner' defined by the lake (Fig. 3 a). The present-day shape (Fig. 3 c) does not allow a corner in contrast to the previous L-shaped form that did. A rectification attempt (according to Molnár et al. 2008) based on ground control points (GCPs) shows that the stated assumption is feasible (Fig. 3 b).

Evaluation of the fluvial pattern

The evaluation of the fluvial pattern in Lazarus' map is somewhat more difficult than that of the lakes. This is due to the fact that the outline of the lakes accommodates to the topographic features, and therefore it is typically more stable, in most of the cases the wave abrasion cannot change them considerably, if the water level remains more or less the same.

In contrast to that, the fluvial pattern, or even the whole drainage system may evolve in various ways. The goal of this paper is to demonstrate that the major watercourses (primarily the Danube) changed their channel (in position or in style) at places since the mapping for *Tabula Hungariae*.

As it was recently considered by Székely et al. (2006, 2007), the 'erroneous' course of the river Danube at the Danube Bend (north of Budapest) drawn in Lazarus' map, can also be partly attributed to the incision and fluvial evolution of the Danube. At other sections downstream there are further examples that can be considered as river avulsion and/or incision. Further, yet less studied differences in river size (assuming that the width in the drawing can be related to a certain order of magnitude of discharge) may also turn to be important in explaining a number of strange historical hydrological observations and settlement names.

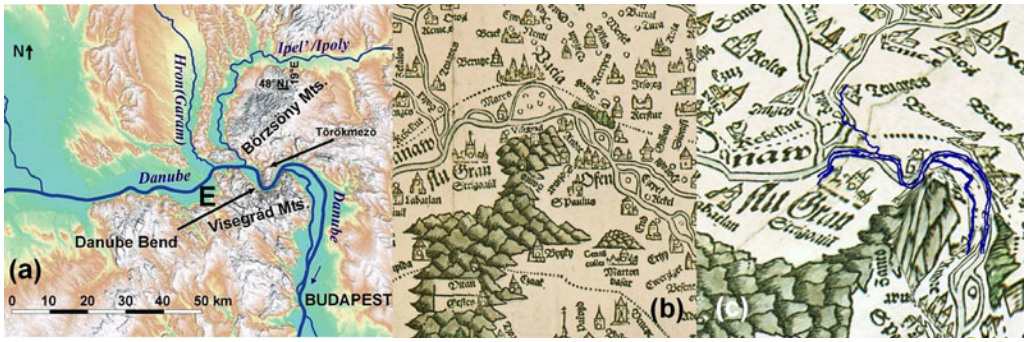

Fig. 4. a) The present-day topography (SRTM DTM, e.g., Farr et al. 2007) of the Danube Bend. E: Esztergom. b) Lazarus did not indicate the spectacular bend, instead island(s) are visible. c) A georeferencing attempt of the Lazarus' map at the Danube Bend: a triangular warping rectification (also known as rubber sheeting) image using settlements and additional features as GCPs (detailed by Székely et al. 2007; blue line: present-day Danube and river Ipoly) verifies that the island was realistic at that time

a) The question of the Danube Bend

Some 30 km N from Budapest there is a spectacular geomorphic feature (Fig. 4 a) forming the so-called Danube Bend. For the first glance, it is not understandable, why this obvious feature is not indicated in Lazarus' map (Fig. 4 b). (Lazarus himself worked within some 20 km distance, in Esztergom.) Instead of the expected curved channel an island is indicated there (Fig. 4 b). A previous study (Székely et al. 2007) pointed out using aerial photographs and georeferencing this part of Lazarus map using ground control points that probably the map drawing was correct at that time, but the island ceased to exist due to river avulsion that happened since then (Fig. 4 c). The geoscientific importance of this observation is that the current channel of the Danube is approximately 1–1.5 m lower than the elevation of the abandoned channel indicated in *Tabula Hungariae*. Consequently, the incision in the last 500 years exceeds 1 mm/year that fits to the other observations (e.g., from repeated precise levellings).

b) Downstream avulsion sections of the Danube

Like the aforementioned disappeared river arm in the Danube Bend, similar processes can be implied in some other sections of the Danube. Downstream, the river course between the present Budapest and the aforementioned Mohács shows interesting deviations from the present day course. Lazarus indicates a number of islands where there are no islands today, or the existing island is too small to be related with the feature represented in the map. In relationship to that some settlements are clearly on the shore of the Danube in the map, but today this is not the case. A primary example for that is the episcopal center of Kalocsa ("Colotzia" in Lazarus' map): it is indicated to be situated at a today not existing arm of the river (see below).

In the Csepel island an easily identifiable settlement is Szigetszentmárton

("S Martinus" in Lazarus' map; Fig. 5). Interestingly it is indicated more to the west as today, if we consider that the present settlement is on the (eastern) Ráckeve arm of the Danube. But this is basically only apparent, while here the locality is situated on a presently not existing small (but western) arm of the Danube. Assuming the validity of the map, we arrive to the conclusion that the small unannotated circle situated on the island depicted here can only be the present day Szigetújfalu ('new village on the island'). In the light of this interpretation its name gets a new meaning. On the opposite (right) bank the locality Ercsi can be identified in *Tabula Hungariae* ("Ertzy"). Apart from the presumably anthropogenic modification of the land surface, the potential (already silted-up) former channel is now below 97 m a.s.l. (reference: Baltic sea), while the average water level of the Danube is somewhat below 96 m a.s.l. here. This difference in the elevation would mean slight relative incision, that is in concordance with other observations (s. below).

Similarly to the aforementioned island, another one is indicated at the (modern) southern tip of the Csepel island: west from the Lórév-Makád line ("Loro" and "Ma$^{\mathrm{k}}$an" (written upside down)) the island is situated in the Lórév-Makád-Adony-Kulcs quadrangle (Figs 5 and 6). The present topographic situation allows the former existence of this island and the course of the national road No. 6 (following here the Roman Road, in other words the Roman fortification line, Ripa Pannonica) has a similar curve that would fit to the course of the Danube. If the assumption holds, the present course of the Danube is approximately in the middle of the assumed former island.

Our next paleo-island downstream is the Pentele-Apostag island that hosts a monastery "Monstor Butibulas" (Fig. 5). A detailed description on the name of the monastery and the debate on the nature of this monastery is given by Gergely (2007). He also reflects on whether this island existed or not: he considers the illustration of Lazarus as partly erroneous, however, the possible existence of the island is not excluded. The author mentions that the position of the island is certainly wrong. However, in the light of the illustration of the other islands, it is feasible to consider the former existence of "Island Butibulas". The sources mentioned by Gergely (2007) regard this monastery as having sort of defensive role as well, therefore installation on a smaller island seems to be feasible. As concerns the positional issue, the present topography allows a former island opposite to the former Pentele (now part of the town Dunaújváros) somewhat in the downstream direction. If the round shaped depression of elevation at 95 m (a.s.l.) is considered as the position of a former channel, it fits to the illustration depicted by Lazarus. As most of the aforementioned cases the final decision could be made based on future ^{14}C or palaeomagnetic analysis of shallow borehole cores of the channel area. In this specific case it would be especially valuable since there is historical evidence that can be related to the results.

Here further two islands are considered: the first one is at Dunaföldvár ("Feuldnar") – Solt ("Solch"; Fig. 5) and the second one is the already mentioned Kalocsa ("Colotzia") island (Fig. 5). In the case of the former one, it is possible to notice how the Danube changed its course: the (western) arm, most probably the forested strip at Bölcske (downstream from Dunaföldvár and upstream from

Fig. 5. The original Lazarus' map showing the central part of the Danube valley and the Lake Balaton. Note the numerous islands of Danube indicated in the map. See explanation in the text (cf. Fig. 6)

Dunapataj ("Patai")) at that time represented the main stream, while today the eastern one (or similar) is the only stream, and the former one is completely abandoned and silted up. The shape of the river arms are very similar to the drawing of Lazarus' map.

The latter island near to Kalocsa (Fig. 5) is less surprising, since there are several very tiny oxbow-lake-style streams in the vicinity (e.g. the Csorna-Foktő channel), the so-called "fok"s. These are remnants of the "fok"-water management system: depending on the precipitation and other factors, the inhabitants managed the water storage (and also the fishing capacity) of these tiny channels. Locality Foktő (foktő – 'the exit and controlling point of the management system') can be considered as the southernmost tip of the island. More to the NNE there is a well-known, 8 km long real oxbow lake, the Szelidi-tó, an aquatic touristic place today. This lake is a good candidate for the a remnant of that river arm. The surprising here is rather the possible age, since this oxbow lake, being situated relatively far away from the Danube, was considered as early Holocene, but certainly not as young as the *Tabula Hungariae* would imply. The fast evolution of the trunk channel of the Danube would mean a considerable incision (in local sense).

Last, but not least it is worth mentioning that the next fortification downstream, Tolna is drawn just beside the Danube in the map (also at a branching;

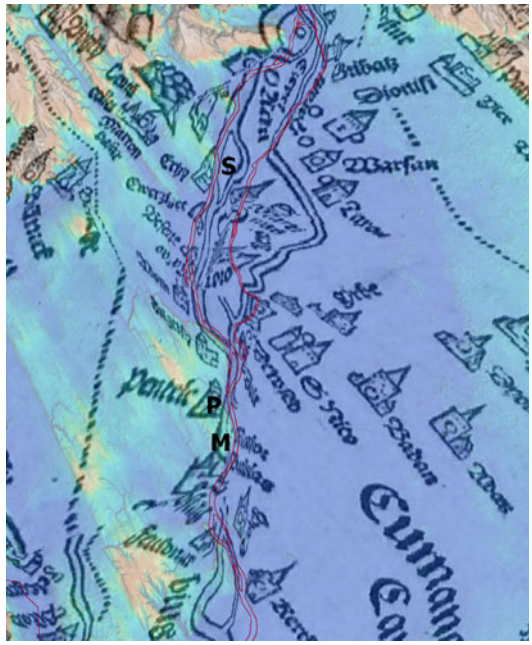

Fig. 6. A triangular warping rectification (rubber sheeting) using the identified settlements as GCPs applying the method of Molnár et al. (2008) for the section of the Danube at Csepel Island (cf. Fig. 5). Shaded relief of SRTM is in the background. S: Szigetújfalu with "Ertzy" (Ercsi) on the other side; P: Pentele; M: "Monstor Butibulas". "Loro" (Lórév) is situated halfway between Pentele and Szigetújfalu (for the sake of clarity it is not annotated). The red lines represent the Danube

Figs 5 and 7). Today, Tolna is found at a major oxbow lake, but far away from the active Danube channel. Assuming that Lazarus was right, the larger arm of the Danube should have been the present day oxbow lake. However, since in this region the Danube is already in the fully meandering zone (having lost the coarse components of the transported sediments taken at the Danube Bend), the elevation change here is much less than in the aforementioned cases (Fig. 7). In other words, the five-century-long changes in vertical sense (e.g., incision) that can be derived from the map, are probably decreasing southward.

c) The question of stream Sárvíz

Tabula Hungariae depicts the river Sárvíz ("Sarwitz flu") as an important watercourse, similar to other, present-day rivers in the basin (Figs 5 and 7). However, today Sárvíz has no such a great importance. There is historical evidence that previously it was used as waterway transport route. It seems that in the 16th century its water discharge was still high enough to consider it important that even its name appears that is uncommon in *Tabula Hungariae*. Unfortunately only a few settlements are indicated in the vicinity, therefore the georeferencing of this particular area of the map has rather large error.

Fig. 7. A "best fit" triangular warping rectification (rubber sheeting) of Lazarus' map for the section of Danube between Budapest and Mohács using the identified settlements as GCPs. The red line indicates the present-day Danube and selected oxbow lakes and some other watercourses. Note that there is no enough GCPs around Sárvíz Stream ("Sarwiz Flu"). See further discussion in the text

Conclusions

The ancient mapmakers were certainly experts in their field. The products of their activity deserve that we respectfully consider their maps and observations. Although there are certainly numerous errors in their work due to various reasons, our first approach in evaluating their work should be the acceptance of their observations. If we consider the mapped objects as representation of the (contemporaneous) geographic truth, this assumption may lead to extraction of valuable information.

In the case of *Tabula Hungariae*, the following conclusions can be drawn:

1. The extent of the major lakes were larger than today, even a major lake, "Lake Becskerek" does not exist anymore. The "river Sárvíz" seems to have had higher discharge than today. These observations support the assumption of a somewhat wetter climate or more equal distribution of the precipitation.

2. The numerous islands pictured along the Danube that do not exist anymore in that form may imply a more braided river dynamical style of contemporaneous state of Danube. This may mean differences in discharge and/or in sediment discharge.

The implied vertical influence is decreasing southward; this implication seems to be in accordance with other (geological, river dynamical) observations. For the verification of these conclusions further studies seem to be necessary: palynological, ^{14}C and palaeomagnetic analyses of material of shallow boreholes may answer some questions in this field.

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